

## Section 2: North American Natural Gas Resources

### *Introduction*

The ability of natural gas resources to meet future demand is a critical question for the nation and the Pacific Northwest. Natural gas resources are estimated by several federal agencies, primarily the Minerals Management Service (MMS), the U.S. Geological Survey (USGS), and the Energy Information Administration (EIA). In addition a business, government and academic group, the Gas Potential Commission (GPC), produces an estimate of U.S. natural gas resources every two years. The National Petroleum Council (NPC) also periodically assesses U.S. natural gas resources. In Canada, a counterpart to the GPC, the Canadian Gas Potential Committee (CGPC) estimates the size of the gas resource base. Two government organizations the National Energy Board (NEB) and the Alberta Utility and Energy Board (AEUB) also make estimates of Canadian gas resources. Unfortunately, the various resource-forecasting entities use slightly different definitions, terms, and methodologies when making their assessments

Natural gas is typically found concentrated in pockets that have been formed within particular types of geological formations (traps) located at certain depth ranges. Geologists group natural gas resources into two broad classes: conventional and unconventional. Natural gas found in concentrated in pockets is referred to as a *conventional gas resource*, and is relatively easy to extract. Conventional resources can be located onshore or offshore and currently account for about 75 percent of U.S. production, a percentage that is projected to steadily decline over the next several decades (EIA 2004). A major subcategory of the conventional gas resource is *associated natural gas*, which is dissolved gas associated with oil production. In the past, much of the extracted gas was associated natural gas, and was often flared or re-injected to maintain oil reservoir pressure. Today, only about 15 percent of natural gas produced in the United States is associated with oil deposits (EIA, 2001). Some of the natural gas produced today is not concentrated in pockets, but is of a more dispersed nature. This dispersed type of gas is referred to as an *unconventional gas resource*, and has subcategories of tight sand gas, coal-bed methane gas, and gas shales resources. Unconventional gas requires special extraction techniques and is more challenging and expensive to extract. In 2002, unconventional natural gas production was just over 25 percent of total U.S. gas production. Over the last 15 years, production from tight sands and coal-bed gas resources has grown steadily and in 2002 accounted for 19 percent and 8 percent, respectively, of U.S. production.

Several key terms are used to describe natural gas resources. Two important terms are *proved reserves* and *potential resources*. The expressions *total resource base* and *technically recoverable resource* are also commonly used terms and refer to the sum of proved reserves and potential resource. A newer and less commonly used term is *commercial* or *economical resource*, which is used to describe the amount of the total or technically recoverable resource that can be brought to market at a specified price using a given set of technological assumptions. Two other related natural gas terms are *annual production* and *cumulative production*. Unlike the other terms above, which are

estimates, these last two terms are actually measured quantities. The media often mistakenly interchange these terms. A brief discussion of the terms used to describe gas reserves and resources is given below.

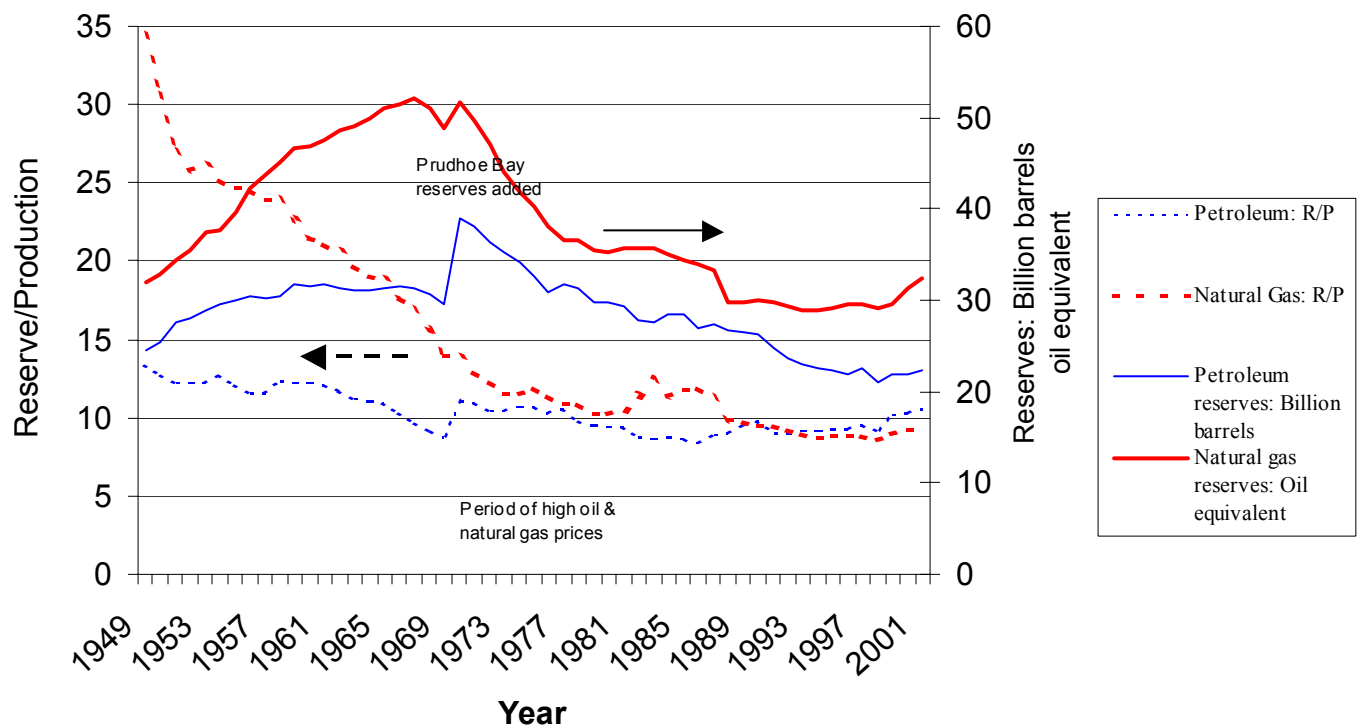
### ***Proved Natural Gas Reserves***

Proved natural gas reserves are estimated quantities that at a particular time are demonstrated by geological, engineering and economic assessments to be recoverable. Generally, under given economic and technological conditions, there is at least a 90 percent probability that the recovered volume will exceed the estimated proved reserves volume. Thus proven reserves are a conservative estimate of the resource available. Market price for natural gas and the level of extraction technology available will influence the proved reserve levels even if there is no change in assessment of physical gas supply. Some entities, such as the GPC, use terms like probable reserves, possible reserves and speculative reserves. These last three reserve categories are technically and economically less secure and have lower probabilities of being brought into production than proved reserves. The probable, possible and speculative reserves in combination are roughly equivalent to the potential resource term described later in this section.

Each year gas production reduces the level of proved reserves in a given gas basin. Exploration and development are necessary to move natural gas from the potential (undiscovered) resource category to the proved reserve (discovered) category. Each year as reserves are consumed, exploration and development replaces some, all, or more than the amount of gas consumed. As a producing gas basin matures reserve additions become more difficult to obtain, and they may begin to fall behind gas production; consequently proved reserve levels begin to fall, and soon after, production will also begin to decrease. The term *reserve to production ratio* (Reserves/production, or R/P) is often used to describe the vitality of a gas basin. Ratios of more than 20 describe a young basin with production expansion potential, 10 to 20 a maturing basin, and less than 10 an older basin that may soon reach a production peak. Technological innovation and higher gas prices can forestall the day when reserve additions begin to fall behind gas production. Less mature gas basins are likely to see increases in both reserves and the assessed potential resource categories on a year-to-year basis.

Figure 2.1 below illustrates the decline in R/P and proved reserves for both U.S. oil and natural gas for the period 1949-2001. Following World War II the natural gas market expanded rapidly, and the R/P began to decline reaching a value of 20 in the early 1960s. Much of the initially developed natural gas was associated gas, or was incidentally discovered during oil exploration. Low regulated natural gas wellhead prices resulted in a rapid increase in gas consumption and the R/P continued its decline through the 1960s and early 1970s. Actual proven gas reserves and production began to decline in the early 1970s, which pushed the government to significantly raise the regulated wellhead price for gas, and later initiate the deregulation process for natural gas in 1978 with the passage of the Natural Gas Policy Act. These actions stimulated a sizable amount of gas exploration, which stabilized natural gas reserves and caused the R/P to increase beginning in the mid 1980s. Since deregulation was completed around 1990, energy companies have developed reserves as necessary to meet projected near term production

requirements. In the 1990s, U.S. gas reserves declined and the R/P reached a low of 8.6 in 1997. Over the last several years high prices have led to increased exploration activity and the R/P has risen to 9.3.<sup>1</sup> The low R/P for natural gas and the nation's experience with long-term low R/Ps for oil and associated declining oil production has caused concern in some quarters that natural gas production will also begin an inexorable decline. While the low R/P could be a sign of a declining resource base, maintaining only sufficient inventory (reserves) to meet near term production requirements is also a reasonable financial technique for energy companies to reduce capital costs: See Appendix A for more discussion about the future sufficiency of the North American gas resource base.



**Figure 2.1: Petroleum and Natural Gas Reserve to Production Ratios: 1949-2001**

Source EIA

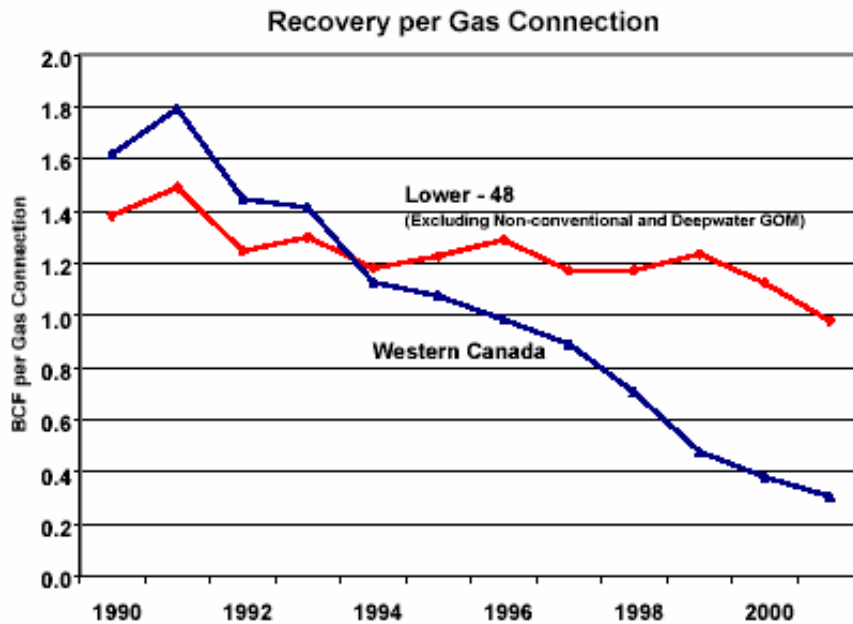
In 2002, additions of 22.8 trillion cubic feet (Tcf), or 118 percent of U.S. gas production (roughly equivalent to 2002 U.S. consumption) were made to proven reserves. During seven of the last 10 years, gas additions to reserves, have exceeded U.S. production: additions exceeded total U.S. consumption for three of the last 10 years (EIA, 2002).

### *Reserve Additions*

As noted above, proven reserves are a conservative assessment of natural gas (or oil) resources. Additions are made to proven reserves by two means: discovery of new fields, and reserve growth. Approximately 20 percent of additions are new fields, and 80 percent

<sup>1</sup> The National Petroleum Council has noted that even though the R/P has risen over the last several years the ratio of actual producing reserves to production has not increased, remaining at around 6.5.

are from reserve growth. Reserve growth is sometimes referred to as reserve appreciation. When estimating total or technical resource base, forecasts are made regarding new field discoveries and reserve growth. Historical geological and production data are used to develop forecasts about the size of the undiscovered fields and the rate and size of reserve growth. Reserve growth is often calculated using a reserve growth or appreciation factor. Recent geological and production data have resulted in downward revisions in forecasted size of new field additions and reserve growth. Figure 2.2 below illustrates the recent downward trend in gas recovery per connection for the U.S. Lower 48 (the 48 state continental portion of the United States) and Canada.



**Figure 2.2: Estimated recovery per gas connection.**

Source NPC 2003

The progressive decline in gas field size and the application of technology to increase initial production rates of the (smaller) fields has resulted in steeper well decline rates. The overall *annual base decline rate* for the U.S. Lower 48 has increased from 17 percent in 1992 to 27 percent in 2001 (NPC, 2003). The annual base decline rate is the decrease in production over one year that would occur if no new wells were added. The increasing base decline rate necessitates increased exploration and drilling activity every year in order to maintain reserves and production.

### ***Potential Natural Gas Resources***

*Potential gas natural resources* are estimated undiscovered resources, which are thought to exist and be recoverable. The primary organizations involved in providing the basic information used to estimate potential gas resources are the USGS, and the MMS.<sup>2</sup> To estimate the quantity of undiscovered gas resources that can be technically recovered,

<sup>2</sup> In Canada the CGPC and the NEB have the responsibility for estimating gas resources.

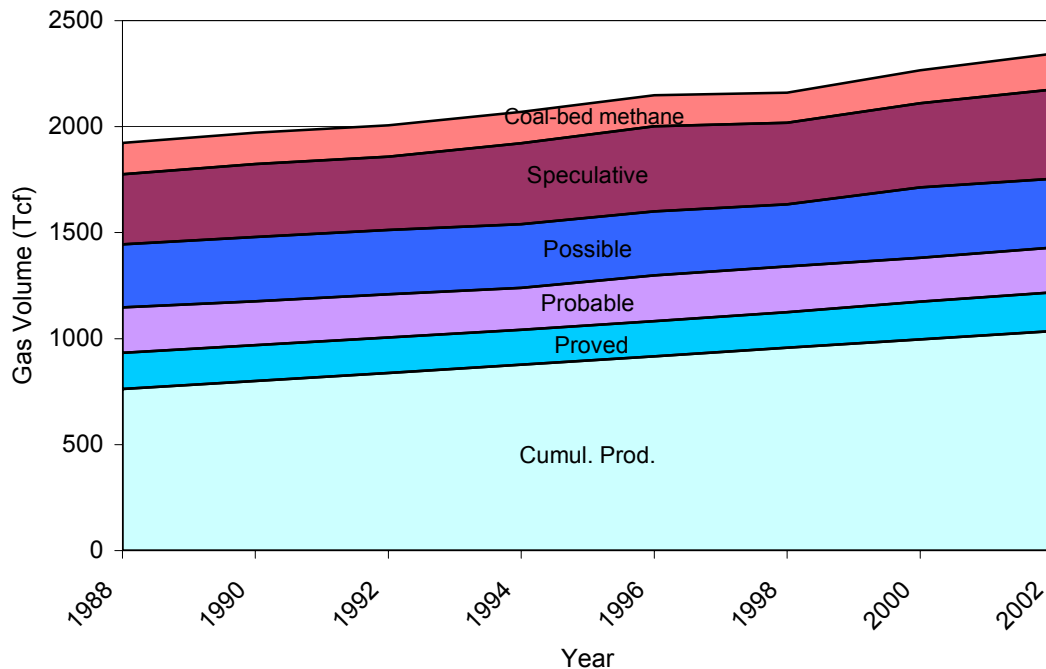
geologist combine existing geological information with previous gas extraction experience. Assumptions about future technological developments are also included in the estimation methodology that the USGS and MMS use to calculate undiscovered natural gas resources. The assumptions surrounding projected extraction economics and technological developments range from conservative to very optimistic. Because of variability in the assumptions used by the different resource estimating entities within each step of the resource estimation process, the final resource estimates can vary considerably. The total technical resource base is the sum of proved reserves and potential gas resources.

The Potential Gas Committee (PGC), a volunteer committee comprised of representatives from industry, government and academia, in 2002 produced an updated estimate of the U.S. total resource base. The PGC estimated potential gas resources at 1,311 Tcf, including Alaska and approximately 1,110 Tcf for the Lower 48. This corresponds to 67 times current annual U.S. production and 58 times current annual U.S. consumption. As table 2.1 below shows the largest percentage increase was in the speculative and coal-bed methane categories.

**Table 2.1: PGC Potential Gas Resource Estimates for 2000 and 2002.**

<b>Resource category</b>	<b>2002</b>	<b>2000</b>	<b>Change</b>
Traditional resources	(Tcf)	(Tcf)	(%)
Probable	210.5	207.0	+1.7
Possible	325.0	332.2	-2.2
Speculative	422.0	397.8	+6.1
Subtotal traditional	958.3	935.8	+2.4
Coal-bed methane			
Probable	17.1	16.3	+4.9
Possible	56.7	54.3	+4.4
Speculative	95.0	84.6	+12.3
Subtotal coal-bed	168.9	155.2	+8.8
<b>Total Potential Resources</b>	<b>1,127</b>	<b>1,091</b>	<b>+3.3</b>
<b>Proved gas reserves</b>	<b>186</b>	<b>177</b>	<b>+5.4</b>

The PGC has estimated the potential natural gas resource since the late 1980s. The PGC's 1988-2002 estimates of potential gas resource, as well as proved reserves and cumulative U.S. production are shown in Figure 2.3 below.



**Figure 2.3: PGC estimates of U.S. total potential gas resource and cumulative gas production.**

Figure 2.3 illustrates several interesting phenomena. First, the estimated total resource base (potential resource + proved reserves) has increased steadily over the observation time period from 1,160 Tcf in 1988 to 1,311 Tcf in 2002, despite continuing gas production of 17 to 20 Tcf per year. Second, the largest increase has been in the speculative and coal-bed methane categories. Finally, cumulative production is rising slightly faster than the remaining total resource base, and may equal the remaining U.S. Lower 48 total resource base by 2010.

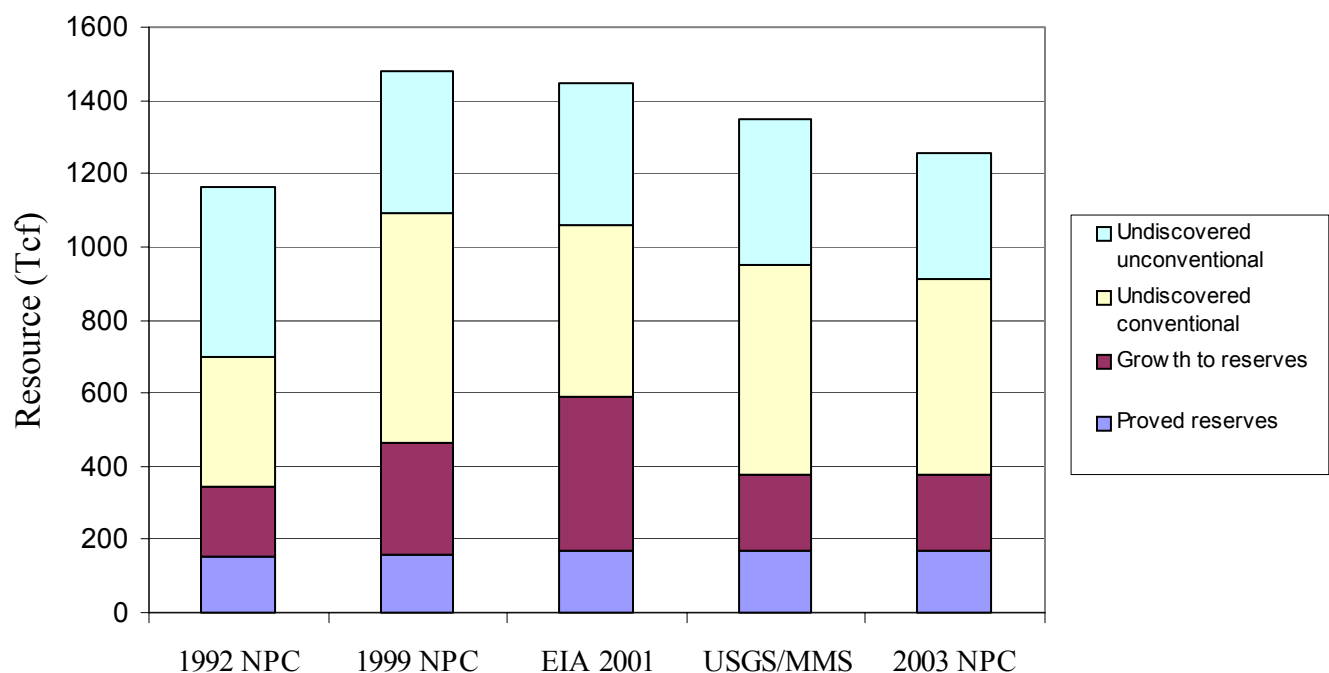
The National Petroleum Council (NPC) has estimated the total U.S. resource base in each of its last three natural gas reports (1992, 1999 and 2003). The 1999 report estimated a total resource base of 1,465 Tcf for the Lower 48, a 171 Tcf increase over the 1992 estimate. However, after a detailed review and a methodology update, the 2003 NPC report showed a reduction to 1,252 Tcf for the U.S. Lower 48 technical gas resource base.<sup>3</sup> This sizable reduction of 211 Tcf was due primarily to lowered expectations for proved reserve appreciation (extensions, infilling wells, etc), and a reduction in the field size (ultimate recovery volume) used for undiscovered fields. The reductions to the

<sup>3</sup> All volumes adjusted to 1999 consumption numbers.

estimated total resource base are based on recent data and reflect an improving understanding of the natural gas resource base at the NPC and the USGS and MMS.

The NPC estimated the total gas resource base for Alaska at 331 Tcf, of which only 9 Tcf was proven reserves, and another 36 Tcf listed as probable reserves. Combining the total resource bases for the Lower 48 and Alaska results in a U.S. total resource base of approximately 1,585 Tcf. While the potential gas resource in Alaska is large, it is not well explored and is essentially a stranded resource.

In its 2001 *Annual Energy Review*, the EIA estimated the total resource base at 1,350 Tcf for the Lower 48. Unlike the 2003 NPC analysis, the 2001 EIA report did not include the recent USGS and MMS adjustments for lowered proved reserve appreciation, a reduction in the ultimate recovery volume for undiscovered fields, or the slight reduction in assessment of the unconventional gas resource. Figure 2.4 below summarizes the recent resource assessments by the NPC, EIA, and the USGS/MMS. All volumes are adjusted to 1999 cumulative production and use the NPC's prediction for advanced exploration and extraction technology.<sup>4</sup> As Figure 2.4 shows the recent assessments have produced significantly lower estimates of the Lower 48 total gas resource base.



**Figure 2.4: Comparison of Natural Gas Resource Assessments-Lower 48**

Source NPC 2003

<sup>4</sup> Defined by the NPC as the (projected) exploration and extraction technology for year 2015.

## ***Economic or Commercial Gas Resource Base***

As defined above, the technically recoverable or total resource base is the sum of the estimated potential resource and proven natural gas reserves. Some of the potential resource will be located in remote or restricted access areas, or in small pools, which effectively removes it from commercial availability. Over the last few years several organizations that evaluate North American natural gas resources have attempted to estimate the economic or commercial gas resource. The NPC in its 2003 report estimated that 60 percent (760 Tcf) of the U.S. Lower 48 total resource base would be available at a long-term Henry Hub price of \$4/MMBtu.<sup>5</sup> At higher prices of \$6 and \$8/MMBtu, the economic resource base was estimated at 74 percent (940 Tcf) and 83 percent (1,050 Tcf) respectively.

The California Energy Commission (CEC), in preparation for its Natural Gas Market Assessment, estimated the Lower 48 state total gas resource at 975 Tcf and the Canadian resource at 417 Tcf. The CEC further estimated that there was 640 Tcf of commercially available natural gas resources in the U.S. Lower 48 and 332 Tcf in Canada (CEC, 2003) at prices projected over the next decade (2004-2013).

## ***Canadian and Mexican Natural Gas Resources***

Canada has significant natural gas resources, 71 percent of which occur in the Western Canadian Sedimentary Basin (WCSB). In 1999, the NPC estimated the total Canadian technically recoverable gas resource base at 667 Tcf, which was a downward revision of 10 percent from its 1992 natural gas report. The 2003 NPC gas report further reduced the estimated Canadian technical resource to 397 Tcf, with current technology, and 475 Tcf with advanced technology. The Canadian Gas Potential Committee (CGPC) in its 2001 (CGPC, 2001) study listed the Canadian natural gas resource (discovered and undiscovered reserves) at 592 Tcf. In contrast to previous studies the CGPC further refined its resource estimate by differentiating between total resource and the nominally marketable resources. Nominally marketable reserves were estimated at only 233 Tcf, and excluded coal-bed methane and some resources located in the Arctic, which have not been demonstrated as economically marketable. Coal-bed methane pilot projects have been initiated, but seem to be hampered by low production rates at the wellhead (Meneley, 2002). A more recent study, which appears to be a counterpoint to the CGPC study, produced by the Canadian Energy Research Institute (CERI), estimated total undiscovered conventional resources at 527 Tcf (Oil & Gas Journal, 2003).

Mexico has revised both its gas and oil resource estimates downward over the last several years in order to follow international resource estimation methodologies. In its 2003 natural gas report, the NPC estimated the total Mexican gas resource base at 121 to 147 Tcf depending on assumptions of extraction technology. This was a reduction of more than 50 percent from the NPC's 1992 estimate of the Mexican resource. An even lower resource estimate was presented by the PGC in 2003: Mexican proven natural gas reserves of 28.2 Tcf, and a total gas resource base of only 50.6 Tcf. Mexico has not been

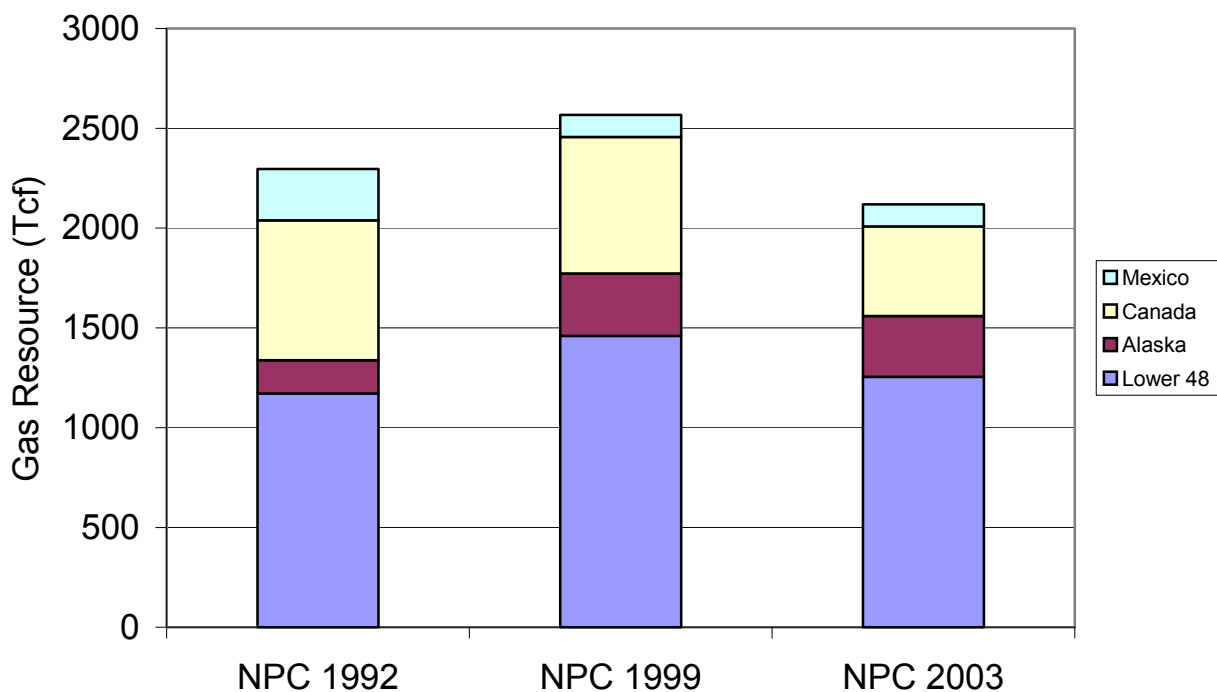
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<sup>5</sup> Henry Hub is the largest natural gas hub in the nation and is located on the Gulf Coast.



as heavily explored as the United States or Canada, so the future resource numbers may be significantly greater.

Figure 2.5 below illustrates the three NPC estimates of the North American total resource base. Note that the NPC did not attempt to estimate the total gas resource for Mexico in the 1999 report: For comparative purposes the NPC's 2003 estimate for Mexico was added to the 1999 total.



**Figure 2.5: National Petroleum Council estimates of total natural gas resource base.**

The 2003 NPC estimate for the North American total gas resource is significantly lower than the estimate made in 1999; roughly 20 percent lower. Estimates for both the United States and Canada were significantly reduced in the 2003 report. In addition the estimated total resource base for Mexico was significantly reduced between the 1992 and 2003 NPC reports. The total resource base for Alaska increased between the 1992 and 1999 reports, but at this time must be considered a stranded resource.

### ***Federal Access Restrictions***

Substantial amounts of U.S. natural gas resources lie beneath federal lands, or areas designated as wilderness, where access is limited by federal regulations. Most of the restricted access resource areas are located in the Rocky Mountain region. Offshore natural gas resources located in the coastal regions on the Pacific, Atlantic and Eastern Gulf of Mexico area are under a federal development moratorium, and are completely unavailable for gas or oil resource development.

In its report on U.S. Natural Gas Markets, the EIA evaluated the impact of reducing, but not eliminating, federal access restrictions in the Rocky Mountain basin and in the three outer continental shelf moratorium zones (EIA, 2001b). The Rocky Mountain region contains 37 percent of the remaining unproved technically recoverable natural gas resources in the Lower 48. A moderate reduction in access restrictions in the Rocky Mountain basins would free up approximately 29 Tcf of natural gas resource, increasing the region's gas resource by about 10 percent. The outer continental shelf moratorium zones are estimated to have unproved technically recoverable natural gas resources of 68 Tcf. In their analysis, EIA assumed that the phased lifting of the continental shelf drilling moratorium would free up the entire undiscovered natural gas resource in the OCS.

A reduction in federal access restrictions in the Rocky Mountain basin, and in the three OCS moratorium zones, would increase the Lower 48 natural gas resource base by 87 Tcf. This represents a 7 percent increase in the potential natural gas resource base. An estimated 62.5 Tcf of gas, located in national parks, wildlife refuges and wilderness areas in the Rocky Mountain region would remain unavailable for development. In addition, approximately 30 Tcf in other parts of the Lower 48 would remain inaccessible. Note that the quantities of natural gas made potentially available due to reducing access restrictions represent a resource that is technically available, but may not be commercially available, though most analysts believe that the exploration and production (E&P) costs are lower for access restricted resources relative to new unrestricted gas resources.<sup>6</sup>

### ***Assessing the NPC Natural Gas Resource Estimate***

The 2003 NPC report contains the most up to date information on the United States and Canadian natural gas resource bases. In the 2003 NPC report, the estimated U.S. resource base was about 14 percent smaller than the estimate in the NPC's 1999 natural gas report. There are several reasons why the actual natural gas resource base available to the nation is less than the 1,585 Tcf cited in the 2003 NPC report.<sup>7</sup>

1. Land use restrictions that severely limit or prohibit access, apply to roughly 205 Tcf of the natural gas resource in the Lower 48 (EIA, 2000). A good portion of this restricted resource base will probably never be developed. For more details see the section on federal access restrictions.
2. The Alaska natural gas resource is currently a stranded resource, and will not be available to the market for at least 10 years. In addition, large portions of this resource, while technically recoverable, are very remote and are not likely to be economically recoverable in the foreseeable future. See the section on Arctic natural gas resource for more details.

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<sup>6</sup> The lower exploration and production costs for access restricted resources are thought to hinder current gas resource development, since a policy change that allowed access to cheaper resources might strand more expensive unrestricted resources that could be developed. North American Natural Gas, American Energy Solutions & Foster Bryan Ltd. 2003.

<sup>7</sup> The sum of the lower 48 state resource estimate of 1,252 Tcf and the Alaska resource estimate of 331 Tcf. Both estimates made assuming NPC advanced (2015) technology.

3. In 2003, the NPC developed estimates of the commercial or economic gas resource base. At a long-term Henry Hub price of \$4/MMBtu the NPC estimated that only 60 percent, or 760 Tcf of the total Lower 48 resource base could be economically recovered using advanced technology assumptions.

## *Summary*

A review of the recent natural gas resource assessments by the NPC, EIA and others revealed the following information.

1. Significant quantities of undiscovered natural gas remain in North America.
2. Recent assessments of total gas resource in the U.S. Lower 48 by the NPC, EIA, GPC and USGS/MMS are roughly equivalent, ranging from approximately 1,250 to 1,450 Tcf. Estimates of the Alaska resource range from 220 to 331 Tcf.
3. The 2003 NPC assessment of the Lower 48 gas resource was 1,250 Tcf, a 14 percent reduction from the 1999 NPC report.
4. The 2003 NPC assessment of Canada's total gas resource fell by nearly 30 percent relative to the 1992 assessment.
5. The 2003 NPC assessment of Mexico's total gas resource fell by more than 50 percent relative to the 1992 assessment.
6. The 2003 NPC assessment of the total gas resource for North America was approximately 2,150 Tcf, nearly a 20 percent reduction from the assessment in the NPC 1992 and 1999 reports.
7. The 2003 NPC resource assessment is based on the most current information, and includes the recent adjustments for lowered proved reserve appreciation, a reduction in the ultimate recovery volume for undiscovered fields, and a slight reduction in the assessment of unconventional gas resources.

The 2003 NPC report, and to a lesser extent the 2004 EIA report, indicate that the natural gas resource base is not as robust as it was thought to be just a few years ago. The takeaway message from the supply section of the NPC report is that supplies from traditional North American gas producing basins will be able to supply only about 75 percent of the forecast long-term U.S. gas demand.<sup>8</sup> Investments and policy decisions will need to be made immediately to insure the nation's gas needs are met in the future.

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<sup>8</sup> This despite the sizable reduction in the NPC's forecast for U.S. natural gas demand in 2020.